Simulation-Based Schedule Analysis

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January 31, 2003

Study Goals

- *Improve understanding of the causes of development phase cost growth*

- *Improve precision and accuracy of weapon system development phase cost estimates*

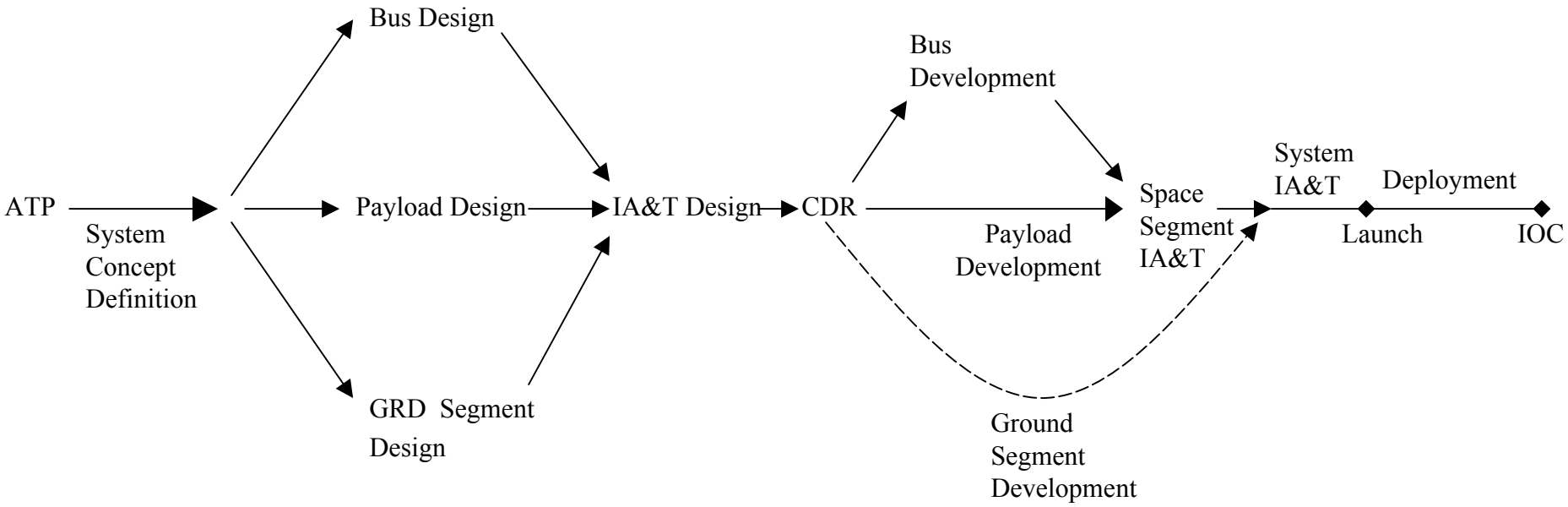
- *Generate ideas for new approaches for development phase estimates*

Hypothesis

For a weapon system's development phase:

- ***Cost is proportional to schedule***
- ***Distribution of activity durations are right-skewed***
- ***People tend to think about activity durations in terms of most likely values, vice means or medians***
- ***Little or no allowance is made to the probabilistic nature of the durations or their network interplay***

Example: Satellite Development Program



Guidelines for Parameter Estimation

- *Quantize schedule uncertainty into three or four levels (e.g, low, medium, high)*

- *For each level, generate statistics (e.g., ratios, percentiles, probabilities) that provide insight into the relative risk assessments*

- *Mathematically relate these statistics to the parameters of the distribution*

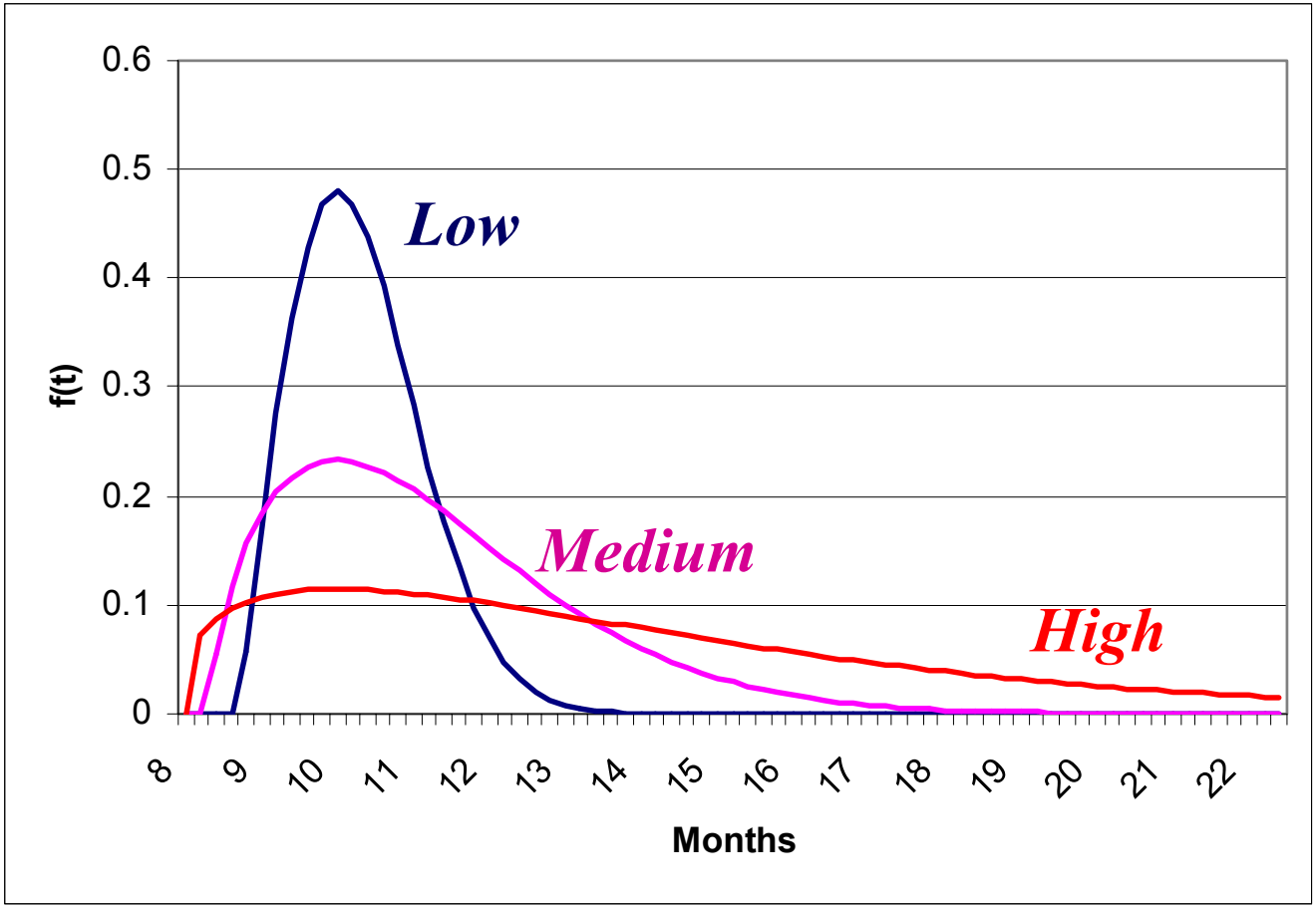
Estimating Distribution Parameters Based Upon a Risk Assessment

Risk Assessment	ML/Low	Pr(t>ML)	ML	a (low)	c (shape)	b (scale)
Input	**By Defn**	**By Defn**	**Input**	**Calculated**	**Calculated**	**Calculated**
Low	1.15	0.60	10.00	8.70	2.04	1.81
Med	1.20	0.70	10.00	8.33	1.55	3.24
High	1.25	0.80	10.00	8.00	1.29	6.41

Measures of Dispersion (Risk)

- ***ML/Low: Ratio of Most Likely (ML) value to Minimum (Low)***
- ***Pr(t>ML): Probability of a duration exceeding the ML value***
- ***Shape Parameter (c=2: Rayleigh, c=1: Exponential)***

Schedule Risk Distributions

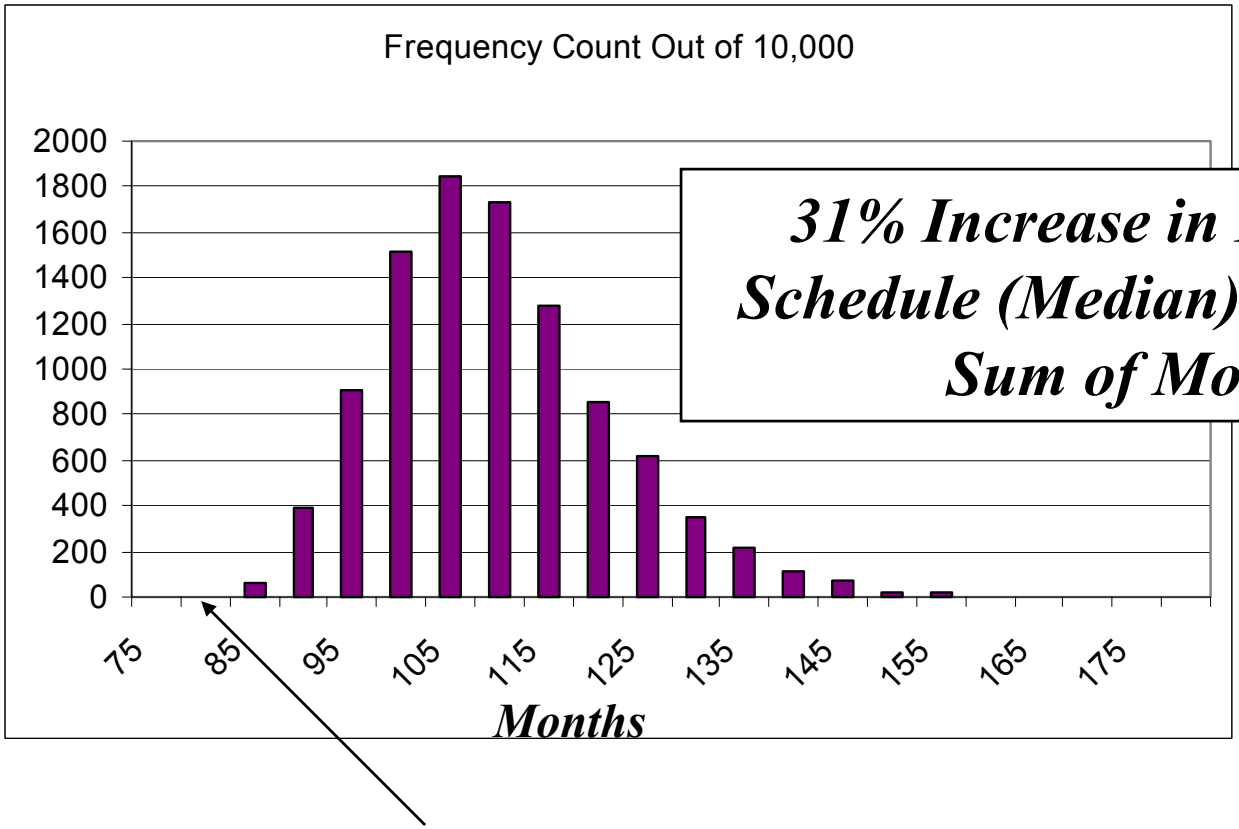


Example Risk Values

RDT&E Program	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
	System Concept Definition	Bus Design	P/L Design	Ground Segment Design	IA&T Design	Bus Development
Risk Level	low	low	high	med	med	low
Most Likely (months)	12.0	9.0	9.0	8.0	3.0	28.0
Predecessor Phases	N/A	1	1	1	1,2,3	5
c(shape)	2.0	2.0	1.3	1.6	1.6	2.0
b (scale)	2.2	1.6	9.6	3.1	1.2	5.1
a (low)	10.4	7.8	6.0	6.4	2.4	24.3

RDT&E Program	Phase 6	Phase 7	Phase 8	Phase 9	Phase 10	Phase 11
	Bus Development	P/L Development	Grd Seg Development	Space Segment IA&T	System Level IA&T	Deployment
Risk Level	low	med	med	high	med	med
Most Likely (months)	28.0	30.0	36.0	9.0	12.0	9.0
Predecessor Phases	5	5	5	6,7	8,9	10
c(shape)	2.0	1.6	1.6	1.3	1.6	1.6
b (scale)	5.1	11.6	14.0	9.6	4.7	3.5
a (low)	24.3	24.0	28.8	6.0	9.6	7.2

Resulting Distribution of Development Completion Time

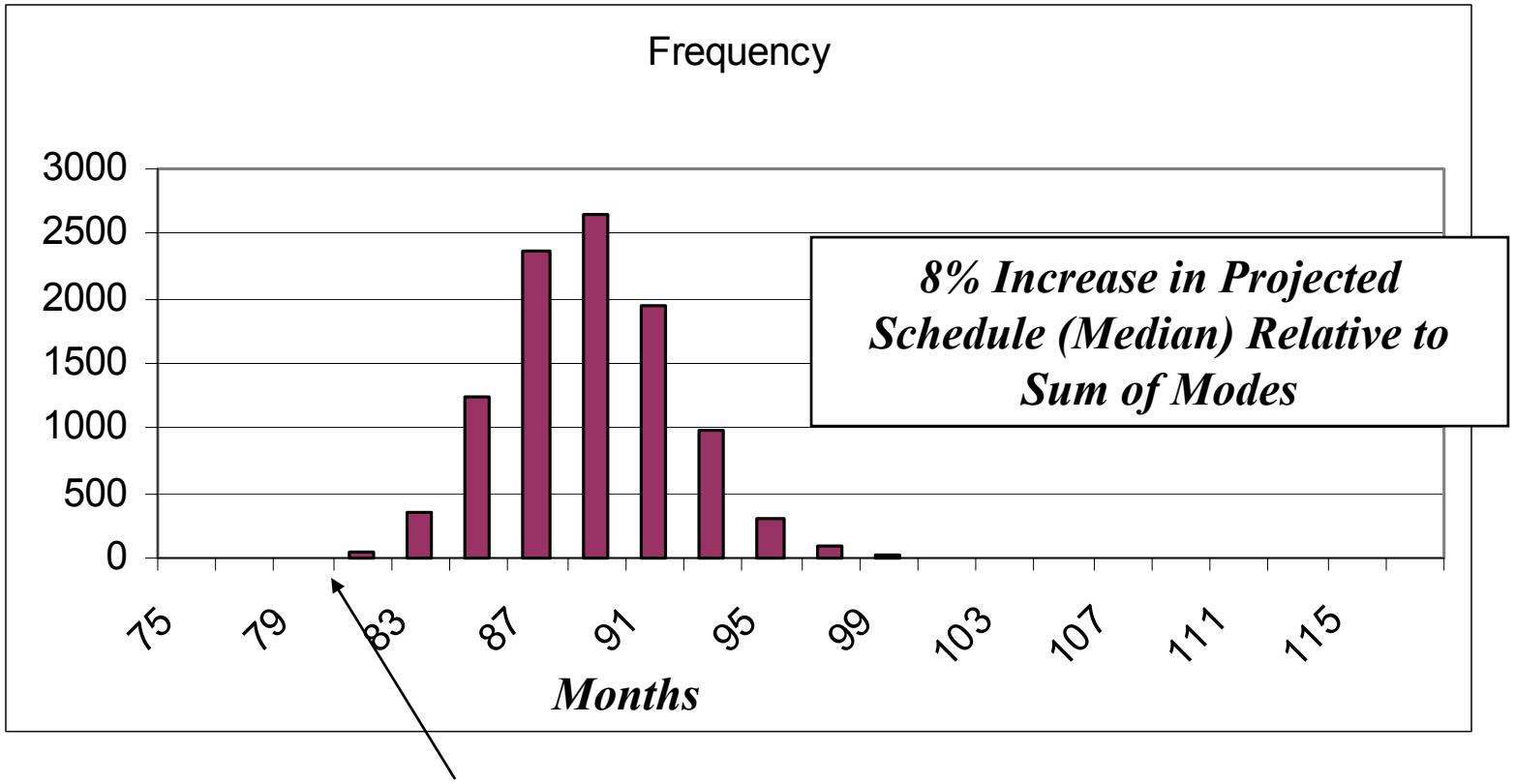


31% Increase in Projected Schedule (Median) Relative to Sum of Modes

Sum of Modes along Critical path is 81 months – Less than 1 percentile

Sensitivity Analysis

(All Risk Assessments Set to Low)



Sum of Modes along Critical path is 81 months – Less than 4th percentile

Implication for Evolutionary Acquisition / Spiral Development Programs

- *EA development activities are fragmented into Blocks and Spirals*

- *Because little data exist to cost EA development programs, each spiral's cost is typically developed based on the contractor's bottom-up assessment*
  - *Estimates are prone to schedule optimism*

- *For budget constrained – schedule unconstrained EA development programs when a capability can be fielded is the critical question*
  - *Schedule models become necessary for independent review groups*

Some Ideas for Improving Methodologies

- ***Development programs should be estimated based on their content not as factors of hardware costs***
- ***Schedule should be a key cost driver of development cost CERs***
- ***Methods for translating planning durations into realistic schedule are needed***
- ***Anticipated and actual schedule data needs to be captured in conjunction with costs***

Conclusions

- ***Schedule optimism may explain much of historical cost growth in development programs***
  - ***– Especially true for EA programs which tend to rely more on bottoms-up estimates for each spiral upgrade***

- ***Program development cost uncertainty (risk) should reflect realistic schedule uncertainty***

- ***Accurate schedule estimation is key to good cost estimates***
  - ***– Even if parametric or analogy approaches are used to develop estimates, relating the estimates to schedule provides a good cross-check***

- ***Methods are needed to more closely link schedule to program development cost***